§47. Materials Design and Related R&D Issues for the Force-Free Helical Reactor (FFHR)

Sagara, A., Muroga, T., Motojima, O.,
Noda, T. (NRI for Metals)
Terai, T., Tanaka, S. (University of Tokyo)
Kohyama, A.(Kyoto University),
Matsui, H. (Tohoku University),

Nuclear properties of induced radioactivity, solid transmutation and decay heat under the 14 MeV neutron fluence of $45 MWa/m^2$ have been investigated on candidate materials for the Flibe blanket in FFHR as well as materials compatibility with Flibe. In FFHR, as shown in Fig.1, which uses the Flibe liquid breeder from the main reason of safety, if there is no need to replace in-vessel materials in the lifetime of 30 years, the reactor can be operated with not only the high safety margin but also a high availability of the plant, resulting in reducing not only the cost of electricity (COE) but also the total amount of radiative wastes.

By considering engineering databases and radioactivity, a ferritic steel JLF-1 (Fe9Cr2W) has been selected as the first candidate for the blanket structural material. Vanadium alloy or ODS steel are second options. If SiC materials is technologically available in future, it gives high thermal efficiency with He gas turbine systems, because the design window of Flibe itself is open and better at higher temperature regions.

After operation to $45 MWa/m^2$ and 100 years cooling, the surface dose rate of JLF-1, V-alloy(V5Cr5Ti) and pure SiC is less than $1\mu Sv/h$, which satisfies the shallow land disposal limits such as Class C limits of US 10CFR61 or the allowable hands-on dose rate of $10\mu Sv/h$. As for bulk impurities, the concentrations of Mo and Nb must be lower than 10 ppm, which is rather severe value and may require advances in materials purification methods beyond present-day technologies.

Concerning solid transmutation, that of W in JLF-1 is remarkable, where W mainly changes to Re, and Re changes to Os. Finally, after the operation of $45 MWa/m^2$, the atomic composition changes from 100% W to almost 10% W, 20% Re and 70% Os. As for V-alloy, since the neutron energy spectrum in Flibe blanket is fairly hard in the range below 100eV, the increase of Cr is estimated to be about 2wt.% in $45 MWa/m^2$. Therefore V-4Cr-4Ti alloy has a sufficient margin regarding to the DBTT shift under the 14 MeV neutron fluence of $45 MWa/m^2$.

The temporal increasing rate of Ta due to decay heat is almost 15°C/s for 100 days and this level is not acceptable. As for W, Mo and Nb, for instance, the rate is less than 0.5°C/s after 1 week cooling, and this level is in the controllable range.

Conclusions are as follows :

(1) The surface dose rate of JLF-1, V-alloy and pure SiC satisfy the shallow land disposal limits or the hands-on dose rate.

(2) The concentrations of Mo and Nb impurities must be lower than 10 ppm.

(3) Studies of materials properties of JLF-1 after transmutation of W to Re and Os are desired.

(4) The V4Cr4Ti alloy has the margin of 2wt.% increase of Cr due to the Flibe blanket.

(5) Temperature rise due to decay heat after 1 week cooling of such as W, Mo and Nb is acceptable except for Ta.

(6) The neutron multiplier Be is expected to reduce the corrosive TF in Flibe, where the research on reaction kinetics are strongly desired.

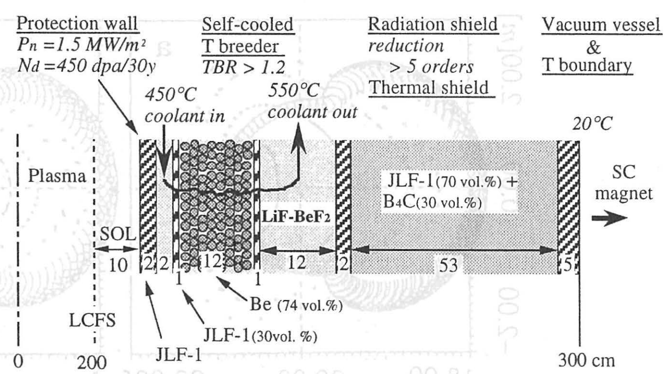

Fig.1 The One-dimensional blanket and shielding structure in FFHR.